

DEVELOPMENT OF A GAMMA RADIATION IMAGING DETECTOR BASED ON A GSO CRYSTAL SCINTILLATOR AND A POSITION SENSITIVE PMT

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An imaging gamma detector was developed using a 5" diameter Hamamatsu R3292 position sensitive PMT and GSO crystal scintillator plates from Hitachi. Plate sizes from 4x4 cm to 8x8 cm and thicknesses from 1.25 mm to 10 mm were used to detect 28 - 35 keV photons from ^{125}I , 140 keV gammas from $^{99\text{m}}\text{Te}$ and 511 keV gammas from ^{22}Na . Several novel features of the detector were investigated including improvement of detector resolution by using anode wire sections and truncated center-of-gravity calculations, and elimination of the discontinuities introduced by using an array of individual plates. Finally, a new concept of imaging light guides made with plastic fibers was tested as a way of coupling the scintillator plates to the PMT and, therefore, enabling construction of large(r) field of view detectors for medical imaging and other applications.

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Summary

We report here results of our extended development effort on a gamma imager utilizing GSO crystal scintillator plates and position sensitive photomultiplier tubes.

Introduction

GSO is a new high stopping power and bright crystal scintillator (see Table I) available from Hitachi [1] which is well suited to detect gamma rays across the spectrum from low energy gammas, such as 28-35 keV photons from I-125, to annihilation gammas from F-18. Recently, as large pieces as 8cm square became available. In this study we tested samples of following sizes: 40mm x 40mm x 1.25 mm, 60mm x 60mm x 10mm and 80mm x 80mm x 2.5 mm. The samples were coupled to two types of position sensitive photomultipliers (PSPMTs) from Hamamatsu: a 3" square R3941 and a 5" round R3292. Our interest in this material is based on the expectation that economical fast and high resolution small field of view gamma imagers will find use in small animal imaging and in specific medical imaging applications.

SCINTILLATOR	NaI(Tl)	BGO	LSO	GSO	YAP
Formula	NaI(Tl)	Bi ₄ (GeO ₄) ₃	Lu ₂ (SiO ₄)O:Ce	Gd ₂ (SiO ₄)O:Ce	YAlO ₃ :Ce
Rel. Light Yield	100	15-20	75	20-25	40
Peak Wavelength (nm)	410	480	420	440	370
Decay Constant (ns)	230	300	12,42	30-60	25
Density (g/cc)	3.67	7.13	7.40	6.71	5.37
Effective Z	51	75	66	59	36
Index of Refraction	1.85	2.15	1.82	1.85	1.95
Hygroscopic ?	yes	no	no	no	no

Table I: Comparison of properties of GSO with other new crystal scintillators and with standard scintillators used in PET (BGO) and single gamma detection (NaI(Tl)).

Experimental Studies

Experimental Setup

The Hamamatsu 3" square R3941 PSPMT and the 5" round R3292 PSPMT were used to image gamma ray sources with plates of GSO scintillating crystal. The R3941 PSPMT has an active area of about 50 mm square while the R3292 has an active area of about 10 cm in diameter. They both have proximity focused parallel dynode mesh structure and crossed wire anodes in x and y coordinates.

Electronics and Data Acquisition System

To reduce the number of individual analogue channels while still retaining the advantage of local readout (as opposed to integral methods such as current division or delay lines) we have used anode wire sectors of two (four) wires each to reduce the number of channels to instrument by a factor of two (four) in R3941 (R3292) PSPMT. The 18x+16y anode wire problem in R3941 was reduced to 8x+8y wire sections while in R3292 the reduction was from 28x+28y to 7x+7y. We have not found a decrease in position resolution by this operation, because lowered granularity of readout was compensated by improvement in the signal-to-noise ratio. The data acquisition system was based on FERA ADCs from LeCroy and a Macintosh Power PC workstation as the host computer running the Kmax data acquisition software (Sparrow Corporation).

Determination of the position of gamma interaction in the GSO scintillator plate was achieved by a calculation of the center of gravity of the signal distribution on the x and y anode sectors of the PSPMT. The electronic signal from the last dynode of the PSPMT was used after inverting and then passing through discriminator electronics to detect an event and determine if the signal amplitude is above a desired background and noise threshold, and to generate an input 150 nsec wide gate to FERA ADCs. All anode sector signals were amplified in LeCroy TRA 1000 amplifiers and delayed by 50 nsec before entering 14 or 16 individual ADC channels.

Results

Figure 1 shows the reconstruction result obtained for a point 0.2 microCurie Co57 source placed directly on a medium resolution parallel hole collimator which was attached in front of the compact detector head. A 40 mm x 40 mm and 1.27 mm thick GSO crystal was used in this test. A 2.4 mm FWHM spatial resolution was measured. At a distance of 5 cm from the collimator the resolution was about 5 mm FWHM.

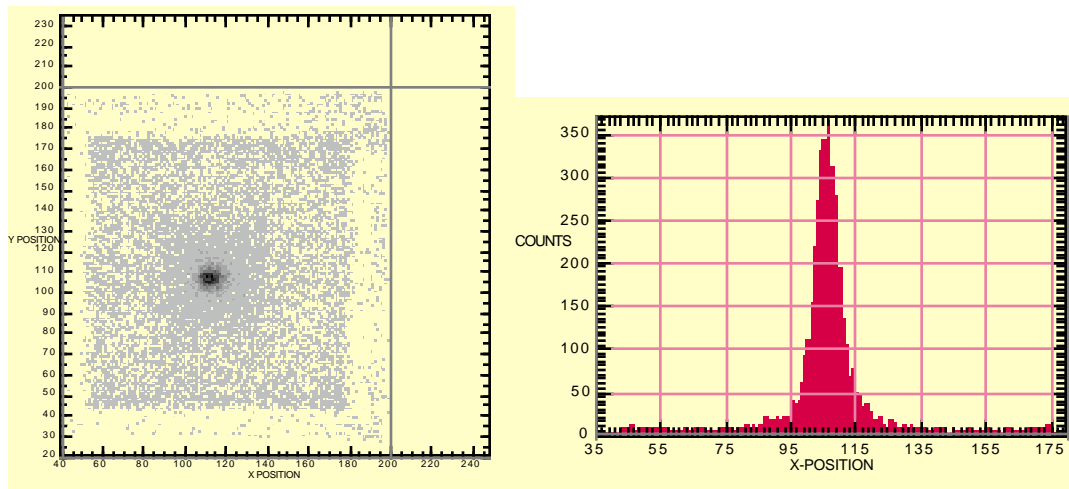


Figure 1. Results obtained for a point 0.2 microCurie Co57 source placed on a medium resolution parallel hole collimator with a 40 mm x 40 mm and 1.27 mm thick GSO crystal.

The second selected result reported in this short summary was obtained with an array of four 40mm x 40mm x 1.25mm tiles placed next to each other in a tight 2x2 array on the surface of a R3292 PSPMT. To minimize distortions at the crystal boundaries the tiles had their edges roughened and painted with a black matt paint to limit reflection. The bottom and top surfaces were polished and a white teflon diffusing tape was used on the top surface. A silicone coupling grease was used to optically couple scintillator tiles to the PSPMT window. An example of an image obtained using a thyroid phantom filled with a Te-99m solution, and a high resolution parallel hole lead collimator is shown in figure 2. About 50% of 140 keV gammas are stopped in the scintillator. The left image shows the raw result with no software correction and the right image was obtained using a simple correction algorithm and image smoothing. The work on improving the image uniformity still continues at the time of this writing and a comparison with a just received single 80mm x 80mm plate will be performed. Detection of 511 keV gammas will be accomplished with a 1 cm thick GSO scintillator piece and a comparison with a 1cm thick BGO will be performed. also using the imaging light guides.

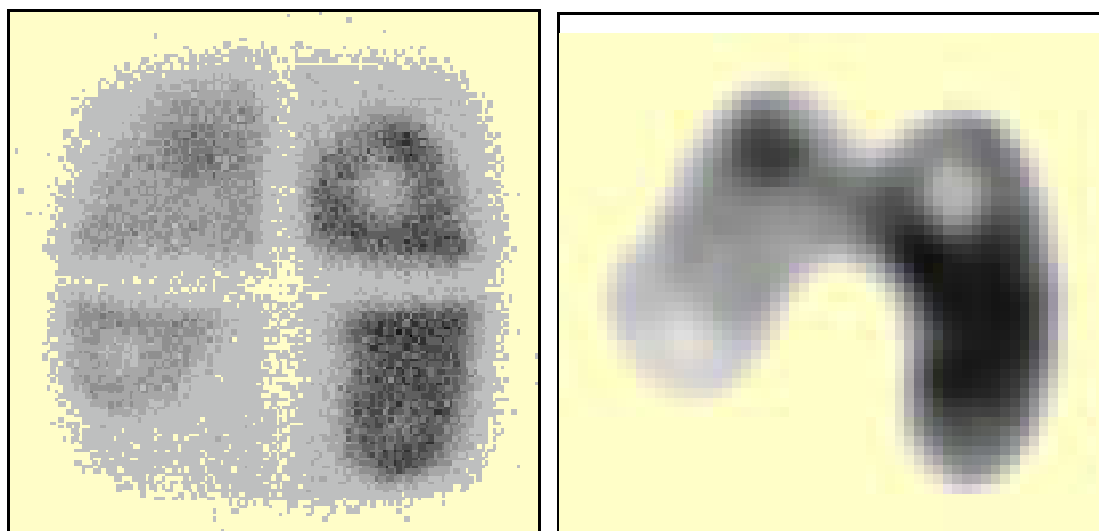


Figure 2. Thyroid phantom image obtained using 4 cm thick high resolution parallel hole lead collimator and an array of four 40mm x 40mm x 1.25 mm GSO plates-tiles; raw image (left) and corrected image (right).

Conclusions

A bright and fast GSO crystal scintillator has advantageous properties making it an attractive solution in imaging gamma rays in a broad energy range from I-125 to F-18. An economical solution is to use an array of tiles to cover the FOV of interest. Beyond the active size of about 10 cm which can be covered with one 5" R3292 PSPMT, an array of photodetectors can be employed. Applications of such a detector include small animal imaging, scintimammography and positron emission mammography (PEM), as well as imaging of thyroid and heart.

References:

[1] Hitachi Chemical Co., Ltd., represented in the USA by Marubeni Specialty Chemicals Inc., White Plains, NY.